Leveraging the Force of Formative Assessment & Feedback for Effective Engineering Education

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Leveraging the Force of Formative Assessment & Feedback for Effective Engineering Education

Abstract

In recent years, there has been a fundamental shift in engineering education from an emphasis on covering content to a student-centric focus on ensuring the attainment of learning outcomes. To ensure attainment of the educational objectives, engineering education thought leaders have highlighted the importance of the development of effective authentic assessment schemes appropriate for the 21st century, and the alignment of assessment and instructional efforts with the planned learning objectives and outcomes. Our focus in this paper is on the use of formative assessment (also called assessment for learning) for engineering education. With formative assessment, an assessment is made of the current learning level and then pertinent feedback is provided to both the student and the instructor so that they can take concrete steps to facilitate learning improvement. This is in contrast with the ubiquitous summative feedback (assessment "of" learning)—in which the main aim is to grade or rank the student by ascertaining their current learning level without really giving them concrete advice on what to do next to improve learning performance. The use of formative assessment can transform students' performance by empowering them with particularly potent "self-assessment" skills through which students become more aware of their learning and know what is it that they should do next (i.e., they become "self-directed"). Formative assessment is equally useful for the teaching staff—by helping them know their impact and tailor the instructional strategy and try to personalize their pedagogy to the individual needs of the students. The main contribution of our paper is that we present an easy-to-understand synthesis of the rich literature on formative assessment and effective feedback. Although there are numerous published books and plenty of research papers in this space, our paper fills the niche of providing in a single paper the main findings and insights of the discipline that can guide engineering educators who want to learn about the best practices in formative assessment.

I. Introduction

A. What is Assessment? Why Assess?

> "*Educational assessment seeks to determine how well students are learning and is an integral part of the quest for improved education. It provides feedback to students, educators, parents, policy makers, and the public about the effectiveness of educational services*." (excerpt from Pellegrino et al. [1]).

Assessment, evaluation, and measurement are important facets of university education. Marzano presented the following definitions of important assessment-related terms by synthesizing the works of various classroom assessment experts [2]:

- **Assessment**: "planned or serendipitous activities that provide information about students' understanding and skill in a specific measurement topic";
- **Evaluation**: "the process of making judgments about the levels of students' understanding or skill based on an assessment";
- **Test**: "a type of assessment that takes place at a specific time and most commonly uses a pencil-and-paper format";

- **Measurement**: "assigning scores to an assessment based on an explicit set of rules"; and
- **Score**: "the number or letter assigned to an assessment via the process of measurement; may be synonymous with the term mark."

In terms of outcome-based assessment (OBA), *Assessment* refers to "one or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes" [3], while *Evaluation* refers to "one or more processes for interpreting the data and evidence accumulated through assessment processes" [3]. Evaluation determines the extent to which student outcomes are being attained.

Broadly speaking, the three primary purposes of assessment are to [1]:

1) **assist learning** (which also entails motivating students to keep up with the work and to provide feedback on learning to the student and feedback to the instructor);
2) **measure individual achievement** (student as well as instructor);
3) **provide accountability** and to **evaluate performance** of course, program, institute.

It is important for the assessment system to play a critical part in improving student learning and classroom teaching while serving accountability and policy purposes for learning is the *raison d'etre* of a university. This calls for balanced assessment systems, which Pellegrino et al. [1] argues depend on three critical principles (3 C's)[1]: *coherence*, *comprehensiveness*, and *continuity*.

B. Types of Assessment

Assessment can be of many types and it does not only refer to an endpoint assessment, which very often culminates with an unseen examination or some form of a written piece of work with an integral oral presentation. Other ways of assessing and collecting evidence can include traditional quizzes and tests, observations and dialogues, projects, performance tasks, as well as students' self-assessments gathered throughout a course.

Broadly speaking, assessment can be divided into summative, formative and diagnostic assessment techniques. These are described next.

1) Summative Assessment

With summative assessment, the purpose is to assess learning—i.e., how well a student is acquiring knowledge and skills, and developing his cognition at a specific point in time. Examples of summative assessment are end-term exams, mid-term exams, and standardized state tests that quantitatively measures the current level of learning of a student. Summative assessment is also called "*assessment of learning*"—to be contrasted with "*assessment for learning*", which is the domain of formative assessment, which we discuss next.

[1]A *comprehensive assessment system* aims at a holistic measurement of learning using a range of assessment methods that are appropriately detailed for the tasks for which the assessment will be used. A *continuous assessment system* is based on the assumption that assessment at all levels is part of a continuous stream of evidence that tracks students' and programs' performance over time.

2) *Formative Assessment*

With formative assessment, unlike summative assessment, the focus is not as much on just measuring the learning of the student [1]. Using the assessment for making necessary modifications to the subsequent instruction is indispensable for the assessment to be determined as formative. In the words of Harvey Silver, "formative assessments are for *aiding*, not *grading*."

The purpose of formative assessment is to principally utilize the information gained through the assessment to guide changes in the instructional and curriculum methodology, in ways that would not be possible without this feedback, for the explicit aim of improving the student's learning. Formative assessment is also accompanied by effective feedback to students [4]. Researchers have shown that effective feedback plays a pivotal role in providing the oft-quoted "two–sigma" positive effects of tutoring [5]. It worth stressing that the formative nature of an assessment is not intrinsic in an assessment: summative assessments (such as a written exam or portfolio submission) can also be used formatively if this is used to evolve instruction and help students improve.

Broadly speaking, formative assessment typically calls for qualitative feedback rather than scores and it helps by making the student learning visible to all stakeholders [6]. A comprehensive meta-analysis of several published works has shown that providing timely and appropriate feedback is near the top of the list of the most effective learning interventions [7]. Several practical formative and summative assessment techniques have been proposed and are described in [8]. An example use of formative and summative assessment in a physics class is provided in [9].

3) *Diagnostic Assessment*

Diagnostic assessments, which are sometimes called pre-assessment—are used to gauge students' prior knowledge, identify student misconceptions, and determine any learning-style preferences. Such assessments typically precede instruction and are similar to formative assessment in purpose and are typically used for facilitating performance and are not graded.

C. Pillars of Assessment

Experts of assessment have now obtained a deeper understanding of assessment [1] and it is postulated that there are three pillars underlying all assessments (Figure 1): (1) **cognition**: a model of how students represent knowledge and develop expertise in a domain; (2) **observation**: tasks or situations through which student performance is observed and gauged; and (3) **interpretation**: an interpretation method for drawing inferences from the obtained performance evidence.

D. Pitfalls of Assessments

> "*(Current) assessment focused on ranking and classifying students, not on developing 21st century skills*"—Eric Mazur.
>
> "*Schools do a good job of turning the learner off assessment and not letting them have power over it. They need ownership of their assessment.*"—Eric Mazur [10]

Many experts have raised concerns about how assessment is done in schools and universities [11]. Eric Mazur, a prominent critic of contemporary assessment mechanisms, calls assessment the "hidden curriculum", as it indelibly shapes students' study habits. This is because what is assessed

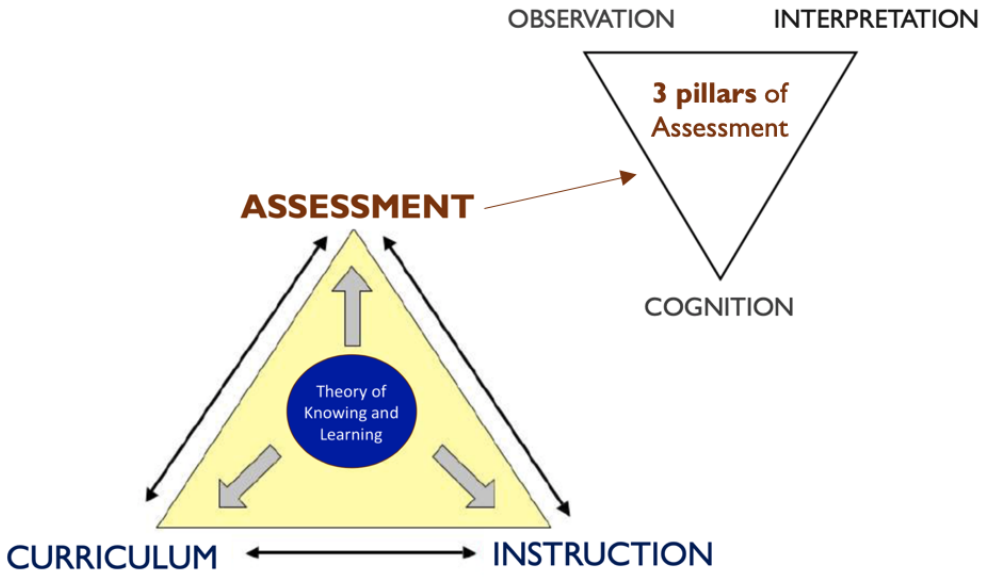

Figure 1: Assessment as an important peg of the educational triad, with assessment itself based on three pillars (Source: [1])

signals what is important to learn and how it it assesses dictates how something should be learned. Mazur also says that improper assessments (those that can be aced through memorization) is the silent killer of learning. Some salient pitfalls with current assessment practices that serve as an impediment to the attainment of 21st-century learning skills are identified here (more details follow later in the paper):

1) **Use of Outdated Cognitive Models**: despite great advances in the scholarship of learning and cognition, many of the current assessment tools are based on outdated cognitive models, which limit their applicability for assessing 21st-century learning.
2) **Non-Alignment**: the assessment is not aligned with the defined long-term objectives and graduation-time planned learning outcomes—for best results, curriculum, strategic vision, instruction, and assessment should be all aligned. In the words of assessment in education expert Jay McTighe, "*What is assessed signals what is import to learn* [...] *How it is assessed signals how it should be learned*."
3) **Non-Authentic**: the assessment is focused on *inauthentic* problem solving and on regurgitation of information and rote learning or application of rote procedures. All testing involves compromise and often tasks are simplified and decontextualized for the sake of precision in scoring, and artificial limits placed on the student's access to resources.
4) **Engendering Risk/Failure Aversion**: common assessment practice based on grading makes students failure averse since the students get punished for making mistakes. Assessment is often incompatible with real-world open-ended problem solving (which often requires and therefore must tolerate lots of failures).
5) **Focused Only On Grading Rather Aiding**: Student assessment should not just monitor, audit, and judge performance but also help improve it.
6) **Lack of Communication**: often the result of the assessment is not understandable to students or the results are provided in ways that do not promote self-introspection or

guide on what steps the student can take to improve learning.
7) **Delayed Feedback**: the failure to provide feedback in time can stunt learning.

E. Challenges of Assessment in the 21st Century

> "*Assessment that is consistent with principles of learning and understanding should: (1) mirror good instruction; (2) happen continuously, but not intrusively, as part of instruction; (3) provide information about the levels of understanding that students are reaching*."—Bransford, Brown, and Cocking, *How People Learn* [12].

Twenty-first century standards and assessments should:

- aim for the development of significant 21st-century skills and be largely *performance-based*.
- should facilitate the development of skills to integrate, synthesize, and creatively apply content knowledge in new situations.
- be fair, technically sound, and valid for purpose, and be versatile and adaptable in the face of uncertainty and unpredictability.
- add value for both learners and teachers.
- make students' learning "visible"(i.e., the assessments should provide a window into students' understandings and the conceptual strategies a student uses to solve a problem.

According to Mazur, most assessment focuses on and encourages *Remembering*, which per Bloom's taxonomy is the lowest level of thinking skills. Assessment rarely reaches the third level of Bloom's taxonomy *Application*, which focuses on the application of learning in new contexts [10]. Furthermore, Mazur charges that in common assessment practice, it is usually the case that tests are performed in isolation even though real problem-solving in the 21st century is collaborative with teamwork and resources being available. The assessment challenges for the 21st century are described in more detail in the following references [13] [14] [15].

F. Contributions for this paper

The main contribution of our paper is that we review the rich literature on formative assessment and effective feedback and synthesize insights that are relevant for engineering education. Apart from providing comprehensive theoretical coverage of the ideas of formative assessment and surveying the views of their major proponents (including Paul Black, John Hattie, Jay McTighe, Grant Wiggins), we also provide a window into the on-the-ground practice by reporting how formative assessment is implemented in practice in various countries around the world.

G. Organization of this paper

The rest of the paper is organized in the following way. In Section II, we provide an overview of the relevant background and describe the various benefits of formative feedback. In Section III, we introduce the various formative feedback frameworks/tools. In Sections IV and V, we provide some insights into the formative value of assessment for *educators* and *learners*, respectively. In Section VI, we present the experience of various educators, including some of the authors, is deploying formative assessment in diverse international settings. In Section VII, some insights, guidelines, and pitfalls are described. Finally, the paper is concluded in Section VIII.

II. Background: Formative Assessment and Feedback

A. Defining Formative Assessment

> "*Assessments that inform teachers about the nature of student learning can help them provide better feedback to students, which in turn can enhance learning*." (Black and Wiliam, 1998 [16])

The basic premise of formative assessment, according to veteran assessment expert, Dylan Wiliam, is that when students are given clear learning goals; frequent meaningful feedback; and opportunities for self-assessment and peer-assessment, *achievement soars*.

Although the term formative assessment goes back a long time—with Michael Scriven in 1967 talking about the term formative assessment in contradistinction to summative assessment [17]—it has not been defined consistently or uniformly within the research literature. As assessment experts Black and Wiliam note [16]: "*formative assessment does not have a tightly defined and widely accepted meaning*." In this paper, we adopt the definition offered by Black and Wiliam that formative assessment encompasses "*all those activities undertaken by teachers and/or by students which provide information to be used as feedback to modify the teaching and learning activities in which they engage*" [16]. It is implicit in this definition that being formative is not a property of an assessment, but refers to how the assessment is used.

The defining characteristic of formative assessment—long recognized by experts such as Scriven (1967) [17], Bloom (1969) [18], and Black (1998) [16]—is that the information gained through assessment is used in some way to make changes rather than be used merely for judging or grading a student. Any assessment that plays a role in the customization of the instructional strategy to facilitate the learner's performance can be called formative. Paul Black, a prominent expert who along with Dylan Wiliam, has written the influential review on formative feedback [16] explains formative feedback through the everyday example of cooking. As the cooking is being performed, the cook periodically tastes the soup to decide if the cooking strategy needs some change (e.g., if it needs more spices). In such a case, the purpose is to change the cooking strategy to facilitate improvement (which makes this akin to formative assessment). On the other hand, once the soup has been made and served to the customer—a final judgment now about the quality of the soup by the customer is akin to summative assessment.

Formative assessments occur along with instruction and can provide ongoing specific feedback to teachers and students on how to improve learning. Formative assessment can contain both formal and informal methods and come in many different hue and variety: e.g., an ungraded quiz, an oral question, teacher observations can all serve the function of formative assessment. The formative assessments serve as aids for sharpening the focus for instruction. Formative assessment are used essentially for aiding learning and these assessments, even if recorded by the instructors should not be factored into summative evaluation and results.

B. Benefits of Formative Feedback

> "*Assessment for learning turns the classroom assessment process and its results into an instructional intervention designed to increase, not merely monitor, student learning*."—Rick Stiggins [19]

In a landmark study, Black and Wiliam (1998) [16] showed through a synthesis of more than 250 studies that formative assessments, in contrast to summative ones, demonstrate the more powerful effect on student learning. The results of this review established it conclusively that students learn best when they receive formative feedback about specific qualities of their work along with concrete advice on what they can do to improve their work. This feedback is also useful since this trains the student in self-assessment, which helps the student understand the main goals of the education and enables them to realize what they need to do to succeed. It has been shown that the powerful effect of ongoing formative assessment on the student's learning is most pronounced for weaker students [16].

C. Type of Feedback Matters

John Hattie provided a synthesis of more than 800 meta-analysis related to achievement in his book Visible Learning in which he noted that "the most powerful single influence enhancing achievement is feedback." To be effective, feedback must meet several criteria that include the following (*the following compilation is informed by*: [20] [21] [22]):

1) Feedback should be constructive/formative

We should realize that generic feedback that takes the form of grades (e.g., B) or exhortations (e.g., "more effort needed") may not be sufficient for informing the student on what precise steps the student can take to address the issue. The way formative information is conveyed to a student and the beliefs about ability and effort affects how students interact with feedback for good or for ill [16]. For best results, feedback should encourage positive motivational beliefs and self-esteem.

2) Feedback must be timely, clear, and specific

Feedback is not equally helpful—feedback is most effective when the assessments are continuous, timely, informative, and related to, and aligned to, the instruction and the learning goals. Effective feedback highlights explicit strengths and weaknesses, e.g., "Your essay was well-organized and interesting. However there is a lack of references to the scientific literature on this topic, which if provided can improve the work further".

3) Feedback should be specific and actionable

Feedback must also be specific and actionable. Grants Wiggins suggests a straightforward test for feedback [23, 24]: can the learner understand from the feedback where the learner has done well and what specific actions can the learner take to improve the next time? can the learner make out from the feedback how and what they need to practice and revise? if not, then the feedback is not specific enough and must be improved to become more valuable for the learner.

4) Feedback must be understandable to the receiver

Sometimes a teacher's comment or the language in a rubric is lost on a student. Using student-friendly language can make feedback clearer and more comprehensible. For instance, instead of asking the student to "document the reasoning process", a teacher may remark in a more student-understandable manner that it is expected that the student should demonstrate the step-by-step thinking process that the student used to arrive at the answer.

5) Feedback should be aligned with goals

Feedback should be aligned with the purpose of the assignment and its evaluation criteria. More specifically, feedback should clarify what good performance is in terms of goals, criteria, and expected standards.

6) Feedback should encourage reflection, self-adjustment, and improvement

> "*[Growth mindset] is about telling the truth about a student's current achievement and then, together, doing something about it, helping him or her become smarter*."—Carol Dweck [25]

Merely providing timely and specific feedback is insufficient: teachers must encourage self-assessment and expect the students to use the feedback to revise their thinking or performance. The teachers should also allow the students to think critically about their work and to reflect on what they need to do to improve [26]. Providing learners with timely, clear, and specific feedback is necessary but insufficient. Feedback should be provided so that one can make adjustments for improvement [27]. In other words, feedback should be positive, have a forward-facing focus, and should aim at furthering learning and improving future efforts.

D. Levels of Formative Feedback

Formative feedback can relate to various levels as per Hattie & Timperley (2007) [28] (see Figure 2), which are summarized next with more details available in [28].

- *Task level*—feedback on how well the tasks are being understood or performed;;
- *Process level*—feedback on the main process that is needed to be perform the task;
- *Self-regulation level*—feedback on the self-monitoring capabilities and how to direct and regulate actions;
- *Self level*—feedback providing personal evaluation and specific feedback about the learner.

III. Frameworks and Tools Relevant for Formative Assessment

In this section, we will discuss some of the well-known feedback frameworks and some tools related to the formative assessment.

A. Assessment for Learning (AFL)

> "*Assessment for learning begins first with the end in mind: a clear vision of what we want our students to look like when they finish a course, a grade level, and eventually graduate must be created before teaching ever begins. This preferred picture of students should include skills and knowledge measured by our state standards but should also consider the many other rich targets we hold valuable to becoming a well-rounded and fully functioning citizen in our society. A collaborative process that involves the community, parents, staff, and students should be undertaken to identify the knowledge, skills, dispositions, and performance targets we want our students to attain*."—Senge et al. [29]

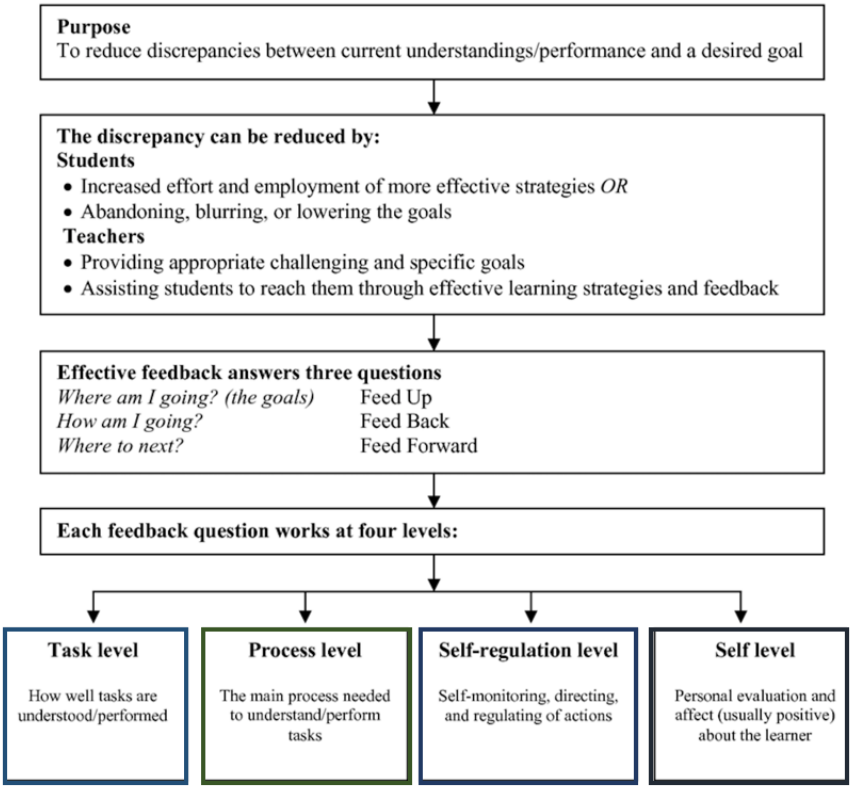

Figure 2: A Model for Effective Feedback (Figure Credit: Hattie & Timperley (2007) [28])

Assessment for Learning (AFL)[2] is an assessment methodology that uses feedback to improve student learning. Normally formative assessment would be considered close to AFL; however, summative assessments could also be considered as AFL, particularly when the outcome and results of summative assessments are used to figure out current deficiencies and decide further strategy.

AFL framework consists of five processes, (1) *questioning*, (2) *feedback by the teacher*, (3) *students' understanding about the expectations*, (4) *students' participation in peer- and self-assessment*, and finally (5) *students' participation in summative assessments*. Through the AFL process, students come out as improved learners having increased confidence and learning independence. AFL is inspired by some assessment and feedback research work in literature, for instance, [28], where the authors describe that the purpose of feedback is to bridge the gap between current and desired learning by providing the information on the strengths and weaknesses of the learning process. As shown in Figure 2, the process starts with the purpose, leading to task distribution between students and instructors to result in constructive feedback for improved student learning.

The main purpose of AFL is to prepare the students well for the summative assessment while in most of the cases, the formative assessments are not graded. As mentioned in [29], formative as-

[2]https://cambridge-community.org.uk/professional-development/gswafl/index.html

sessments continuously provide an opportunity to the learners to demonstrate their understanding while progressing towards a summative assessment.

According to Wiliam [30], AFL can also take the shape when the teaching methods are adapted according to the evidence gathered throughout the student learning process. It is stated that the process of assessment for learning begins with making the learners clear about the learning outcomes and the success criteria. The instructors are then responsible for engineering effective classroom discussions. These discussions should enable the instructors to provide feedback on student learning while encouraging the students to engage in the peer-assessment and support process. The whole process should culminate in the student realization that they are the owner of their learning.

B. Understanding by Design (UbD): A Well-Known Framework for Assessment

In the very influential Understanding by Design (UbD) framework [31] proposed by Grant Wiggins and Jay McTighe, the following three stages of planning a curriculum/learning program are described:

Stage One—Identify the Desired Results: In the first stage of UbD, the instructor plans the learning goals or objectives of the lesson, unit, or course.

Stage Two—Determine Acceptable Evidence of Attainment of Desired Results: At this stage, the important question is to deliberate over what evidence would be sufficient for establishing that the students have attained the desired learning goals.

Stage Three—Plan Learning Experiences and Instruction: In the UbD framework's last stage, the instruction/curriculum/teaching strategy is planned.

UbD is called backward design since it recommends that we postpone the planning of the teaching strategy to the end rather than to begin with it as is common practice. The initial steps with UbD deal with the planning of the the big-picture "understanding" and educational objectives and appropriate evidence that can establish the attainment of these objectives. According to the authors of UbD, the six facets of understanding—the capacity to *explain, interpret, apply, shift perspective, empathize, and self-assess*—can serve as indicators of understanding.

1) Guidelines on Assessment from UbD

In [32], the authors McTighe and Wiggins highlight the importance of properly designing the assessments and the assessment timeline to support smooth learning for the students. The authors provide the following guidelines regarding assessment:

- Instructors should plan deeply about the evidence of understanding they are looking for when the students undergoes an assessment process.
- Instructors should think of assessment not as one-off events but *more like a scrapbook of mementos and pictures than a single snapshot.*
- Instructors should not only seek correct answers. Instructors should understand that a thoughtful assessment system does not seek only correct answers. A thoughtful formative assessment process seeks to bring a culture of change so that thinking, speculations, and misunderstandings can be aired.

- Instructors should welcome evidence of misunderstanding as this information is incredibly valuable to teachers—as this indicates a plausible but unsuccessful attempt at knowledge transfer. Once the misunderstanding is demonstrated, the instructor can change their strategy and design their plan in a way that can replace the misunderstanding with the correct understanding.

From the UbD framework, it is evident that learning is more effective when students understand where they are in their learning. This entails the following [31].

- **Students can and should take more responsibility for their learning. This means they need help to**: (1) reflect on their own and their peer's work; (2) learn from each other than relying solely on the teacher; (3) identify learning strategies that work for them; (4) become more autonomous and independent learners.
- **This means the ability to know**: (1) what they already know that will help them; (2) what they need to learn next; (3) how they are going to learn it; (4) how they can judge if their efforts were successful.
- **Every student can progress, improve, and have a sense of achievement. This means they need**: (1) focused, personalized, and actionable feedback; (2) not to be ranked or compared to their classmates; and (3) to feel able to take risks and try even when things are difficult.

2) Authentic Assessments

> *"Simulating the real-world environment with media or by actually being in a place where that particular skill or knowledge is used in the world—supplying a more authentic context for learning—increases the chance that a lesson will be remembered and can be used in other similar situations*." (excerpted from Trilling and Fadel [33]).

One critical principle of good testing is that it should assess what is important. In assessment, it is all too common to test what is easy to test instead of what is important to test—this is sometimes referred to as the *streetlight fallacy*, referring to the joke about a drunk man looking under the streetlight for the keys he had lost elsewhere just the area under the streetlight is better illuminated. Boaler describes in the context of Maths education how tests typically assess what is easy (narrow procedural mathematics) rather than what is important and valuable (broad creative and real-life like mathematics) [34]. It is suggested to make the assessments that do not only invite a single correct answer but admit multiple approaches as is common in real-life problems. In this regard, Wiggins and McTighe [31] suggest keeping in view the relevant *Goal, Role, Audience, Situation, Performance, Standards* (shorthand: GRASPS) for creating meaningful performance tasks.

In addition, traditional questions in common assessment exercises are often based on recall/ remembering. These questions compared to real-life performance tasks are overly simplified and do not match do not accurately capture the complex open-ended features of real life. In order to escape the pitfalls of such narrow old-school assessment techniques, it is important to adopt what Grant Wiggins calls authentic assessment [35]. Such an assessment scheme is characterized by the following salient features [35] [31]:

1) it is realistic and it simulates or replicates the real-life context in which people come across such work in their workplace;

2) it assesses the student's ability to effectively use a knowledge base and skills to understand and deal with an open-ended complex problem;
3) the student is required to demonstrate practically the relevant knowledge, skills, and attitudes;
4) it does not place artificial constraints and allow the student to practice and consult resources, obtain feedback, and work in teams.

C. Technology for Formative Assessment

Technology can play a very important role in providing feedback to tutors about their students' performance as well as feedback to the students by the tutors to improve student learning during the course. The use of online tools like Slido[3], Piazza[4] provide tutors the facility to run live in-class and out-of-class polls to assess the student understanding of the concepts in real-time. This provides quick and timely feedback to the tutors on how well their students have been understanding the discussions and how the course progress should be shaped for future sessions. The use of technology in assessment can bring together a wealth of data that a tutor can use to go beyond the assessment of the learning outcomes for a course. Identifying, for example, students learning styles, specific difficulties and successes to certain types of pedagogical approaches and providing elaborate analysis and monitoring of students learning and success, are some of the powerful benefits of collecting data using technology in formative assessment opportunities.

Technology can help in the coordination of teams of tutors on large scale courses and assist in the delivery of feedback in a more prompt manner to large cohorts of students. Technology can allow tutors to have a more open and transparent dialogue with their students via blogs and other forms of discussion forums that engage students and mirror social approaches to learning. This is in addition to the use of electronic quizzes and other types of supported virtual learning environment (VLE) question types which allow a very quick turnaround of scoring and provide students with immediate feedback. The horizon of formative assessment using technology can further be expanded by adding some form of intelligence embedded in the VLE to develop and adapt how formative feedback that can be tailored to the specific learning challenges.

Technology can also be used to directly map the students' learning and performance to course learning outcomes, which allows tutors to change in real-time the emphasis on coverage of curriculum depending on the level of achievement of the learning outcomes mapped to the formative assessment. The is helpful for both the student and the tutor as prompt feedback improves student engagement and success, while reducing workloads of tutors who are often challenged by the burden that formative assessment can pose on the top of mandatory summative assessment. A sophisticated implementation of feedback using multimedia approaches composed of audio and video, such as presented in [36], also provides a feeling of personalization which improves student understanding of the feedback and enhances the feedback impact.

[3]sli.do
[4]https://piazza.com/

IV. Formative Value of Assessments for Educators

> "*The major purpose of assessment in schools should be to provide interpretative information to teachers and school leaders about their impact on students, so that these educators have the best information possible about what steps to take with instruction and how they need to change and adapt*."—John Hattie.

In this section, we describe the value of formative feedback for educators and how educators can become more effective by learning and using formative feedback methods. Insights from the related research literature are presented next.

A. Educators Should Know Their Impact

> "*Educators need to understand what each student already knows, and where that student needs to go next in the teaching process. They need to be experts in using an array of interventions to help get their students to success, and to evaluate the impact that they've made*."—John Hattie.

> "*Far and away, the most effective teaching intervention we found was what I call "visible learning": raising the quality of the feedback teachers receive about their impact*." —John Hattie.

> "*Know thy impact*"—John Hattie.

It is important for educators to have a keen eye on how they are impacting student learning. Educators should always ask the following questions: "*Did the teachers and school leaders interpret the reports correctly? If not, we needed to change the reports. Was there a consequential action from the reports?*"

B. Being Empathetic and Having The Right Mind Frame

> "*A successful educator sees learning through the eyes of the students*."

Empathetic teaching focuses on getting feedback about what the student does and does not know and work backward from that. In this regard, Hattie has defined ten mind frames for educators describing how effective instructors think about feedback and formative assessment [37] (a summary is presented in Table I). It is important for the educators to train their students on receiving and providing constructive feedback from others. In particular, the teacher should encourage both (1) student-to-teacher and teacher-to-student feedback; and (2) peer-to-peer feedback, and the students should be trained to proactively seek feedback from peers (individually or in groups) to enhance their work. Further, they should be trained to inquire about the rubrics that will be used to evaluate their work and to utilize it effectively to develop their work [38].

C. Focus on Evaluation Not Only on Assessment

Evaluation focuses on extracting actionable insights from collected assessment data. Hence, it is a process that is essential for both faculty and students. The faculty evaluates planning, procedures, and outputs. The student evaluates the media of instruction, the teaching and learning environments, and the grades obtained at the end of the semester. Standardized digital questionnaires covering all the aspects of teaching and learning.

Table I: Hattie's Ten Mind Frames for Educators [Source: [37]]

Mind Frame 1. I am an evaluator of my impact on student learning.
Mind Frame 2. I see assessment as informing my impact and next steps.
Mind Frame 3. I collaborate with my peers and my students about my conceptions of progress and my impact.
Mind Frame 4. I am a change agent and believe all students can improve.
Mind Frame 5. I strive for challenge and not for simply "doing your best".
Mind Frame 6. I give and help students understand feedback and I interpret and act on feedback to me.
Mind Frame 7. I engage in dialogue much as monologue.
Mind Frame 8. I realize that knowing and communicating success criteria is critical.
Mind Frame 9. I build relationships and trust so that learning can occur in a place where it is safe to make mistakes and learn from others.
Mind Frame 10. I talk about learning, not about teaching.

V. Formative Value of Assessments for Learners

A. Benefits of Self-Assessment

The importance of self-assessment to students has been well recognized in the literature [39]. When students understand the assessment standards and provide timely feedback, they serve in the role of teachers that provides opportunities to develop cognitive and behavioral skills, including self-management and critical thinking [40], promote active learning with students being assessors [41], and understand the assessment standards to improve their works in the future [42]. Self-assessment enables students to understand what are the goals in learning and how well they are making progress towards the goals, and subsequently to evaluate their respective progress towards that goal as time goes by. When this is applied to future workplaces, students learn to examine themselves critically, particularly their professional strengths and weaknesses, which helps to promote continuous professional development and lifelong learning.

B. Challenges of Self-Assessment

Nevertheless, self-assessment is not preferred by students, who are perceived to be novice learners for being unlikely to provide reliable and accurate feedback [43]. While such belief may be untrue, the pervasive belief that students are unsuitable to provide feedback hinders the effectiveness of self-assessment [44]. Besides, students must learn to overcome the time and resource constraints to learn and conduct self-assessment. Hence, producing assessment-capable learners is important to address these challenges.

C. Assessment-Capable Learners

Assessment-capable learners are radical change agents who are active, involved, and engaged. They know where they are, where they're going (based on clear learning intentions & success criteria), and their next steps to move forward). Specifically, they can answer the following *three important questions* [45]: "*(1) What am I learning? (2) Why I am learning it? (3) How will I know when I've had success and have learned it?*"

Assessment capable learners have eight mind frames (see Table II) and have six key characteristics (see Table III). Assessment-capable learners are eager to co-construct learning with teachers. They are active learners who understand the goals in learning, which helps them to perform self-assessment in an accurate manner based on the success criteria. Such practice helps the learners to understand their next steps, which ensures that they are making progress towards

the goals. Hence, they can set goals in learning, then self-monitor and evaluate how well they are making progress towards the goals, The self-assessment skill can be extended to peer-assessment, which helps assessment-capable learners to provide reliable and accurate feedback to their peer learners.

Table II: Hattie's Eight Mind Frames of Assessment-Capable Learners [Source: [46]]

Mind Frame 1. Want to know what success looks like.
Mind Frame 2. Like challenging goals.
Mind Frame 3. Want to master and have deep learning.
Mind Frame 4. Are confident that they can learn.
Mind Frame 5. Want to become their own teacher.
Mind Frame 6. They engage in dialogue (not monologue) on how they learn.
Mind Frame 7. Like to implement their learning goal.
Mind Frame 8. Want to be strategic in their learning goals.

Table III: Six Characteristics of Assessment-Capable Learners [Source: [45]]

1. **Know** their *current level of understanding*.
2. **Understanding** where *they're going and are confident to take on the challenge*.
3. **Select** *tools to guide their learning*.
4. **Seek feedback** and *recognize that errors are opportunities to learn*.
5. *Monitor progress* and *adjust their learning*.
6. **Recognize their learning** and *teach others*.

VI. Using Formative Assessment: An International Report of Experiences

In this section, we will look at the experiences of educators from various parts of the world including UK, Singapore, Egypt, and United Arab Emirates, and China. We will also share the experience of a transnational education program between the UK and China and discuss how the formative feedback has been playing its role in the transnational education setup.

A. Formative Assessment in UK Universities

In many UK Higher Education Institutions, formative assessment over the last 20 years is being integrated into course specifications. For instance, in [47] the study of a three year project is undertaken to produce effective formative assessment approaches with emphasis on quality enhancement and curriculum development resulting in enhanced student learning. In the so-called post-92 universities, which before 1992 used to be Polytechnic Institutes, their teaching-intensive culture made feedback processes play an integral part in the students' continuous learning as in [48] with academicians embedding such practices within the curriculum to further students understanding and motive learning. These more regimented and structured approaches have been also integrated as part of quality audits by professional bodies who have a keen interest in the outcomes, the content and the process of education. For research-intensive institutions, the levels and nature of formative feedback have very much concentrated on the pedagogy of the instructor. This has seen a less formal approach but not necessarily less effective, as the staff-student-ratio at the more traditional institutions has often been 50% or less of the numbers the post-92 universities see in tutorial classes. The opportunities for formative feedback have recently been a fundamental part of the UK student-centred agenda in higher education, with students having a full expectation that the process of learning converges to one where students are treated within

the parameters of a service level agreement, and therefore assessment quality is too expressed by the fundamentals of monitoring the learning and giving direction to the student so much as grading the learning for ranking purposes.

B. Formative Assessment in Singapore Universities

In the context of Singapore, in particular in the private sector, feedback is often and to this day overlooked. As mentioned in [49], the educational system is mostly characterised as exam-oriented. The pressure is on academic success and the responsibility is culturally on the student to achieve the learning outcomes within a fully independent learning culture. It is no surprise that students are often more than not taught what to think not how to think. This to a certain extent promotes a pedagogical approach where feedback is not on the agenda of an academician. The simple publication of solutions to exercises will suffice and it is the students' responsibility to do well. The Singapore private education regulatory quality framework, EDUTRUST is also not converging to practices that support formative feedback and continuous monitoring of learning for student success and motivation. In fact, not a single of the main criteria of the Singapore EDUTRUST framework mentions formative assessment and feedback as a criterion. The public sector, much like the traditional UK universities leaves to the academician the implementation of techniques to motivate and formatively assess students.

C. Formative Assessment in Egyptian Universities

More like Singapore, the assessments in Egypt are examination-dominated where examinations are a mean to assess the student capabilities for the further opportunities [50]. Often coordinated with an approach of practice make perfect in learning. Repetition of exercise with varying levels of difficulty is used to master knowledge and skills and improve cognitive levels. Often the feedback is given verbally as the tutor engages in simultaneous generation of the solution to small problems with students in the classroom environment. Exercise sheets are also given which helps consolidate knowledge. Many of these marked and given feedback by teaching assistants. However, these are not marked to count as part of a summative diet of study but with the sole intent to mirror the approach and to stimulate continuous learning.

D. Formative Assessment in UAE Universities

In the UAE, feedback trends have been influenced by both Australian, United Kingdom and United States practice due to the number of successful transnational higher education partnerships in existence and the appetite of Arab students from this region for the global education standards. As an example in [51] a study is carried out to evaluate the impact of formative assessment in science classes in Al-Ain City, UAE. This is a step different from the regulatory modes seen and practiced in other nations. Once more the academician relies on his own pedagogy rather than on quality frameworks to promote continuous learning and feedback.

E. Formative Assessment in a UK/China Transnational Program

We will now present an example of the use of in-class formative feedback in the context of a transnational education program between the UK and China. The joint program has over 2000 students with each class having 200–300 students on average. This large number creates a huge

challenge for the instructors to provide summative as well as formative feedback. One of the experiments performed at this joint program was about using the students as partners to develop formative assessments and provide feedback [52]. In this project, a set of senior students on a Year 1 course of Microelectronics Systems were selected as student partners who contributed to the development of formative assessment. The student performance on the assessment was not only peer-reviewed but also categorized by the student partners in 5 categories ranging from *Excellent* to *Poor*. The purpose of classifying the student performance in categories was to provide the feedback to a cluster of students belonging to a category instead of individual feedback. The clustered feedback resolved the problem of the painstaking task of individual feedback for large classes while maintained the objectivity and targeted nature of the feedback. The impact of this experiment was measured from the comparison of results of the two cohorts for the same course. It was found that the students who were provided formative feedback attained around 10% higher average score as compared to those who were not given formative feedback.

One common approach most of these countries have is the current and ongoing exploration of pedagogical tools which allows feedback systems to have a deep impact on continuous learning and assessment. The use of Moodle quizzes has been widely adopted and many academics embrace the virtual learning environment (VLE) to communicate with students in ways that guide their learning and synthesize the current state of learning in a particular cohort so that students can collectively and with a community spirit receive information which is seen as feedback for learning and openly discuss it with other peers. The opportunities of feedback extending to further learning have increased with this community and social approach by using VLEs such as Moodle.

VII. Insights & Guidelines

In what follows, leveraging insights proposed by formative assessment experts [30, 31, 53], we summarize the formative assessments best practices and caution against possible pitfalls.

A. Assessing with the End in Mind

It is essential for getting good results that an assessment should be designed with the end in mind. In this regard, the assessor principally pursues three main elements—evidence, the extent of achievement, and assessment reliability [31]—as described next.

- The *evidence* element is concerned with demonstrating that the course objectives have been achieved. A substantial aspect of this is appropriating the assessment techniques to the target outcomes. As noted by Eric Mazur [10], today's assessment should focus on "developing 21st-century skill", and not on "ranking and classifying students". Further to the point, "any question whose answer can be found through Google is not an authentic assessment question".
- Understanding the *extent of achievement (or attainment)* entails the review and analysis of student work. These assessments should not be one dimensional and should embrace various forms including traditional quizzes, tests, performance tasks, and checks of understanding (using oral questions, open-ended prompts, observations, or dialogues).

- Along with other tools, rubrics can serve as a tangible core for formative assessment that is open to replication, validation, and revision [54]. This directly relates to an assessor's third pursuit—*reliability*.

B. Thinking Like an Assessor

As recommended in [31], instructors should adopt the assessor mindset during the design and conduct of their courses. Thinking like an assessor requires that the instructors keep in mind the following basic questions: (1) what evidence are we looking for as a stamp of the attainment of the defined goals; (2) is this proposed evidence valid and reliable (i.e., does it enable us to reliably infer a student's knowledge and skills); and (3) what specific characteristics are we looking for in the performance to measure the extent of attainment of the desired results. Keeping this in mind, the assessor has access to a continuum of assessments that vary in terms of scope (simple to complex), time frame (short-term to long-term), setting (decontextualized or authentic contexts), and structure (directed work to unstructured). These assessments can include checks of understanding (using methods such as oral questions, observations, dialogues, open-ended prompts); performance tasks and projects; as well as traditional quizzes and tests.

C. The Importance of Coaching

> "*Even when it comes to coaching, there are two distinct types: (1) coaching for performance; and (2) coaching for development*."—The Coaching Habit [55]

As noted by Mortimer Adler in "The Paideia Proposal"[5] (1984) [56], coaching of performance is an essential component of teaching apart from the didactic or direct instruction. In recent works, the importance of coaching for enhancing performance has been documented and it has been argued that everyone can benefit from coaches [55, 57]. It is important therefore that teachers act as mentors and coaches and not as mere presenters and judges.

D. Remarks on Some Practical Aspects

- The effective use of formative assessment requires a deep shift of attitudes of educators, students, parents about testing and learning. It is essential for students to be enacted as partners in the formative assessment process. This will enable the students to acquire experience in self- and peer-assessment. The ability to self-assess is in fact an important facet of understanding—as listed by McTighe and Wiggins who enlists the 6 facets of understanding as explain, interpret, apply, shift perspective, empathize, and *self-assess*.
  Numerous techniques for self-assessment have been proposed in literature. For example, the "one minute essay" strategy—in which students at the end of each class reflect on their learning experience and answer questions such as: (1) What was the "big point" learned in the class today? and (2) What is the main unanswered question that you have on your mind—is particularly simply and useful [31]. This exercise, followed by group deliberation and summarization, instills reflection and awareness in the learner, and was recounted by Harvard University professors as one of the most effective innovations they have tried in their teaching [58]. Similarly, peer-assessment trains students in introspection and offers another key tool that can help in scaling up formative assessment in large-scale settings.

[5]Paideia (also spelled paedeia) referred to the rearing and education of the ideal member of the polis or state.

- A practice that targets efficiency is pacing the frequency of major feedback. For example, instead of working to provide detailed feedback on every aspect of each assignment, the instructor can focus on key assignment elements that are reasonably spread during the term. An added benefit of this approach is allowing the instructor to exercise rigor and purposefulness in the marking. The approach also works to avoid overwhelming the students with substantial feedback and remarks to process and act upon.

E. Potential Stumbling Blocks

> "*Yet formative assessment itself involves a change in instructional practice: It is not a regular part of most teachers' practice, and teachers' pedagogical content knowledge may be an impediment to its realization*." (excerpt from Pellegrino et al. [59])

- Institutions must abandon the view that formative assessment is an auxiliary and terminal procedure to one that embeds formative assessment as an intrinsic practice that is synergetic with the institution's operation and objectives. Formative assessment should also be allowed to proceed with a genuine interest in improvement, and not with concern to consequences. This applies to instructors and students as well as administrators. However translating this vision into practice is not always seamless and practical challenges can arise [60]. It becomes important therefore to learn from the best practices on how to effectively institutionalize formative assessment [61] [62].
- Realizing the potential of formative assessment requires buy in from both students and the instructors. This is a subtle and challenging aspect of formative assessment. On the one hand, instructors need to be trained on different modes of facilitation and the importance of formative assessment. On the other hand, enabling student engagement requires the kindling of an urge and ability to seek, receive, and manage feedback. The buy in can be reinforced through a supportive and aligned environment.
- The design of formative assessment processes relies on a balance between assessment objectives, effectiveness, and efficiency. Undoubtedly, extensive assessment procedures risk both redundancy and ambiguity and can impact the efficiency of the student or the instructor. It is therefore important to manage this tradeoff judiciously.

VIII. Conclusions

In this paper, we have provided a broad overview of formative assessment and feedback theory and have provided guidelines for educators as well as students on benefiting from formative assessment. Formative assessment can be transformative for students who can become more aware of their learning and know what is it that they should do next (i.e., they become "self-directed"). Formative assessment is equally useful for the teaching staff and their effectiveness can substantially grow as they learn how to tailor and personalize their instructional strategy according to the individual needs of the students. The main contributions of our paper are that we review the rich literature on formative assessment and effective feedback and synthesize insights that are relevant for engineering education separately for educators and students.

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